LABORATORY STUDIES OF POLAR ICE PROCESSES

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LONG TERM GOALS

The long-term goals of our work are to use laboratory experiments and satellite observations of the ice cover to understand the interaction of waves and sea ice. We will use this information in regional-scale studies of the ice cover growth and retreat.

OBJECTIVES

Our objectives are to measure in the laboratory the way in which waves and sea ice interact, and to compare the results with existing theoretical models, and field and satellite observations. Specifically, we are using laboratory results to determine the role of ocean swell and wind-waves in the growth of sea ice in open water regions such as polynyas, and satellite observations to help understand the processes governing the large scale summer retreat of the Arctic ice edge, and also the role of the sea ice in the Japan Sea in the generation of the Liman coastal current.

APPROACH

Our approach in our various projects is as follows. First, in our waves and ice work, we are supervising a graduate student, Karl Newyear, who is using laboratory measurements and mathematical analysis to determine the interaction of waves with frazil and pancake ice. Second, in our ice ablation studies, we use satellite and meteorological observations to determine the magnitude of the southward ice flux in the Tatarskiy Strait of the Japan Sea, and the role of this flux in the generation of an ice edge and coastal geostrophic current. Finally, in a smaller project, we use statistical analysis of the air temperatures measured by the Soviet North Pole drifting ice stations to show that during the past thirty years, there has been a spring/summer warming over the Arctic Basin.

ACCOMPLISHMENTS

During the past year, we completed our laboratory studies on the growth of frost flowers on the surface of young sea ice, where this work is published in two papers (Martin et al., 1996; Nghiem et al., 1997). The Martin et al. paper describes the interaction of infrared radiation with the flowers; the Nghiem et al. paper describes the interaction of radar. Second, the first part of Karl Newyear's thesis which describes a laboratory and theoretical study of wave propagation through thick layers of frazil ice has been accepted by the Journal of Geophysical Research (Newyear and Martin, 1997). The second part of his work, on the application of an existing theory of wave propagation through a thin layer of frazil ice is being prepared for publication.

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Third, we have participated in a joint paper on the use of wavelet analysis applied to SAR images to define polynyas and track ice floes (Liu et al., 1996). Fourth, we published a paper on the interaction of the ice retreat with potential Taylor columns in the Chukchi Sea (Martin and Drucker, 1997). Fifth, we published a short paper in Geophysical Research Letters on a spring-summer warming of the Arctic temperature field derived from analysis of the Russian North Pole drifting stations (Martin et al., 1997). Finally, we completed a paper which is submitted to Deep Sea Research on the contribution of the ice cover of the Japan Sea to the Liman Current (Martin and Kawase, 1997).

SCIENTIFIC/TECHNICAL RESULTS

First, our completed frost flower work shows that the presence of the flowers means that the sea ice has an infrared temperature which is 4-6 C lower than the physical surface temperature. The flowers and their associated upward brine flux also generate a patchy rough surface on the young ice, so that the radar backscatter undergoes a transient increase to that of multiyear ice. Second, our frazil ice work shows that this ice can be modeled as a fluid with a viscosity which is four orders greater than that of water. This large viscosity means that for surface wavelengths comparable with the frazil ice depth, the observed wavelength increases by as much as 40% above its open water value. Third, our ice ablation work shows from remote sensing data in the Chukchi Sea that the summer ice retreat is partially controlled by the interaction of the melting ice with possible Taylor columns which form over Herald and Hanna Shoals. We find that these columns trap cold water over the shoals, so that the ice above the shoals melts two-to-three weeks later than the surrounding ice. An on-going investigation shows that similar processes occur in the Barents Sea. Fourth, our Geophysical Research Letters paper describes the analysis of thirty years of the Soviet North Pole station temperature data, and shows that for 1960-1990, there was a statistically significant warming during the Arctic spring and summer, which may be related to the recent increase in the amount of summer open water. Finally, our Japan Sea work shows that the winter flux of ice out of the Tatarskiy Strait is sufficient to modify the regional surface temperature and salinity structure and to generate an ice edge and coastal geostrophic current.

IMPACT FOR SCIENCE APPLICATIONS

Because the frost flowers modify the infrared and electromagnetic signature of young sea, this work is important for studies and operations which involve the monitoring and surveillance of sea ice properties and extent. The studies of ice ablation and of the ice retreat in the Chukchi Sea work are important to our understanding of the ice response to atmospheric forcing, and of how the ice edge retreats in summer. The statistical study of the Arctic Ocean air temperature field, which shows significant warming in spring and summer, may be a sign of global warming in the Arctic, or alternatively an example of recent climate fluctuation. Finally, our Japan Sea work shows that satellite coverage can provide information about the interaction of the ice dynamics with ocean processes in this interesting region.

TRANSITIONS

We have completed our frost flower work, and our student Karl Newyear is scheduled to finish his PhD thesis on frazil ice interaction with the ocean waves. Finishing this work should complete our present set of tasks.

RELATED PROJECTS

Our experiments on interaction of radar and frost flowers were done at the Cold Regions Research and Engineering Laboratory (CRREL), as part of a cooperative experiment under the ONR Electromagnetics Initiative with Don Perovich, Ron Kwok and Son Nghiem. We also, at the request of the National Ice Center, sent them copies of our frost flower video, our papers, and our SAR images showing the transient brightness increase associated with the flower growth, in hopes of incorporating our frost flower work into the ice operations area.

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